

# IC4.3 The Formation of Barrier Jets and Gap winds Through Guadalupe Pass

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## 1. Introduction

Forecasting the southward propagation of cold fronts that move through the west Texas High Plains into the Trans Pecos region is a daunting task. The Trans Pecos in west Texas is affected by robust cold fronts during the winter and spring seasons. These fronts generate barrier jets and gap winds along and through Guadalupe Pass (Fig 1). The generation of the barrier jet, if the cold air attendant with the front is not too shallow, can split from the main flow and pass through the gap producing high winds. This paper will discuss the generation of the barrier jets and the formation of a secondary circulation known as gap winds through and along Guadalupe Pass over the Guadalupe Mountains in southwest Texas. An image of the Guadalupe Mountains is shown in figure 2.



**Figure 1.** A map of Guadalupe Pass through the Guadalupe Mountains.



**Figure 2.** A picture of the Guadalupe Mountains. Image was taken from the Terra Galleria Photography. [www.terrageria.com](http://www.terrageria.com)

## 2. Barrier Jets

Strong low-level mesoscale winds often develop adjacent to steep terrain away from the tropics. These winds are commonly referred to as barrier jets (Loeschner et al. 2005). Barrier jets can reach speeds greater than 30 m/s (Olson et al. 2006). Enhanced winds within the jet have a significant impact with the direction along the terrain. These types of jets occur when a cold anomaly associated with a high pressure perturbation develops across a barrier and the low-level flow becomes blocked (Loeschner et al. 2005). The cold air anomaly could be the result from a source region such as arctic air funneling southward east of the Rockies, or adiabatic ascent over the barrier, such as cold air damming (Olson et al. 2006). The magnitude of the stability of the air will result in forced ascent to become restricted and appreciable deceleration occurs leading to the development of the barrier jet (Parish 1982).

The Froude number represents the flow of the air around a two-dimensional terrain feature. (By definition the Froude number is defined by

$$Fr = U/(NHm) < 1. \quad (1)$$

Where  $U$  is the low-level flow speed perpendicular to the barrier,  $N$  is the Brunt-Vaisala frequency, and  $Hm$  is the effective mountain height. When the flow towards a two-dimensional feature is blocked,  $Fr < 1$ , the wind can accelerate down and along a barrier pressure gradient to produce a barrier jet. For long barriers, such as in the Guadalupe Mountains, an approximate geostrophic balance will develop in the cross-barrier direction. Once this occurs, an antitriptic balance will occur over the along-barrier direction (Olson et al. 2006). The terrain acts to force the motion, and the “barrier” winds become confined to the levels below the crest and extend some distance away from the mountain. The distance is dependent on the pressure field provided by terrain-damming (Parish 1982).

Parallel terrain winds generated by the mentioned mechanisms above are known as “classical” barrier jets. Classical barrier jets are assumed to be a quasi two-dimensional terrain induced flow that impinges towards a barrier (Olson et al. 2006). This type of jet develops along the Guadalupe Mountains in the winter and spring seasons. As the jet develops along the mountain range, a secondary

response circulation will emerge if the air mass is not too shallow and where a gap present. The secondary circulation has the capability to produce high winds through the pass. High winds are defined as sustained winds of 40 MPH or greater or gusts reaching 58 MPH or greater.

### 3. Gap Winds

Gap winds form when a significant pressure differential develops between the entrance and exit regions of a gap. The pressure differences along a two-dimensional gap (entrance and exit region) are formed by several types of weather patterns. Cold air surges are the most common type of weather pattern that produces gap flows (Gabersek and Durran 2004). In west Texas, these cold surges are generated from cold fronts attendant with high pressure moving south along the eastern edge of the Rocky Mountains.

Gap winds can be explained by using linear theory when investigating stagnation points within the flow itself. Flows with constant  $N$  (static stability) and  $U$  (the velocity vector for wind) while using linear theory with simple convex barrier can imply the behavior of stagnation points. Stagnation points will develop along the lee or along the wind-ward slope of the ridge depending on the behavior of the ratio of the cross-flow to the along-flow of a barrier. This ratio is defined as

$$E = NH / U \quad (2)$$

( $E$  is the non-dimensional mountain height,  $H$  is the height of the convex barrier, and  $U$  is the velocity vector of the wind). The aspect ratio,  $B$

$$B = (\text{length of the ridge} / \text{width of the ridge}) \quad (3)$$

determines whether the flow will become broke or the flow will split (Gabersek and Durran 2004).

In cases where the aspect ratio  $B$ , is greater than 1, the stagnation point will lie within the region above the lee-side of the slope. This occurs when the ridge is oriented perpendicular to the flow. When  $B$  is less than 1, the stagnation point will lie on the wind-ward side of slope attendant with the split and deflection of the flow around the side of the ridge. This occurs when ridges are aligned parallel to the flow (Gabersek and Durran 2004).

When a gap is present within a two-dimensional feature (a ridge), the flow has the capability to move through the gap rapidly towards the lee-side of the barrier. This flow will move rapidly away from the mountain by the continuation of the accelerated gap flow. Durran published a study on stagnation points and found that when he produced results such that  $E$  equaled 1.4 (while using  $N = .01$  per sec and  $U = 10$  m/s) a zone of high winds (jet within the gap) would occur at the exit region of the gap (the ridge within the model was perpendicular to the flow) (Gabersek and Durran 2004).

The study found that the jet was flanked by a pair of vortices in which the circulation was opposite to that of a barrier without a gap. The high-amplitude wave aloft attendant to the reversed flow occurred downstream from the ridge. When this circulation is present high winds develop in the wave breaking region at the gap's exit (Gabersek and Durran 2004). Winds past the exit region of the gap will be the strongest while winds prior to the gap will remain light (Ford). Gap winds through the Guadalupe Pass are generated by the process mentioned above during the winter and spring months.

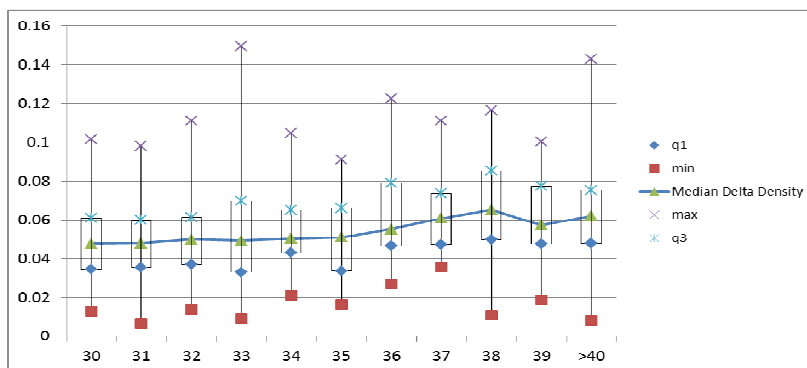
## 4. Midland Texas Gap Winds Research

Cold fronts that surge into the Trans Pecos region which are generated by an arctic air mass and follow the Rocky Mountains southward will generate an easterly wind component to the front. The cold air mass associated with this type of front needs to be slightly modified and not be somewhat shallow to allow for the secondary circulation known as “gap winds” to occur. If the air mass is shallow enough, the primary circulation known as the “barrier jet”, will dominate and light winds will prevail through the pass.

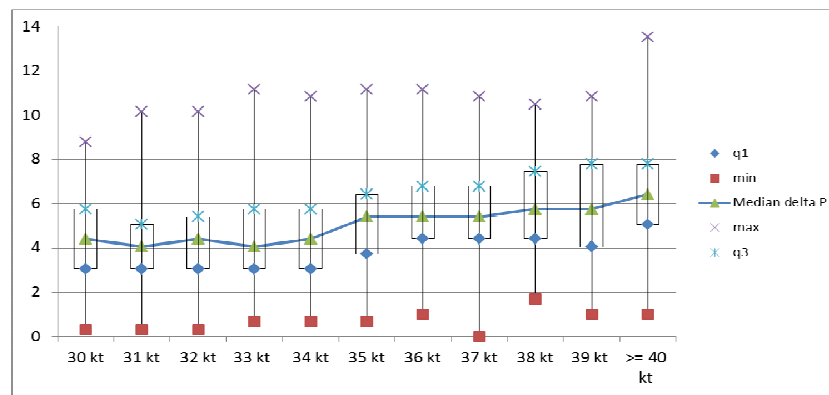
A research project is currently underway to understand this process. High wind events from March 1992 to December 2011 were analyzed. High wind events were confined to cold fronts that progressed southward along the Rocky Mountains. The main focus of the study is to understand why some cold air mass surges produce high wind events and other produce relatively calm winds. Observations were collected from KCVS and KELP to see if correlations existed with the pressure and density fields to produce high winds through the pass. (See Figures 1 through 3 for results). Further research will be done to look at the potential temperature and pressure perturbation fields to see if a more concise explanation exists.

Ryan Barnes (NWS Meteorologist, OUN) and I will continue to investigate and build a climatology database for gap winds through the Guadalupe Pass to improve forecast warning lead times and to understand how these types of fronts impact west Texas.

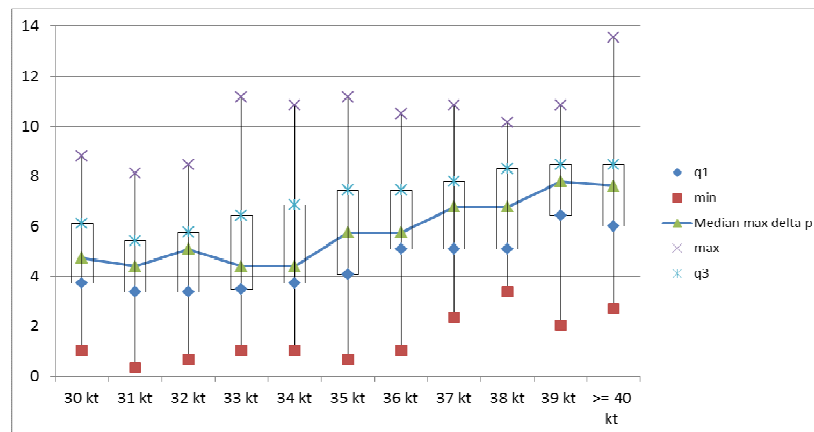
## 5. Results



**Figure 3.** The graph above shows the medium change in density from ELP to CVS from March 1992 to December 2011 for high wind events through Guadalupe Pass. The high wind events caused by cold air surges into the region. (Graph produced by Ryan Barnes)



**Figure 4.** The graph above shows the medium change in pressure from ELP to CVS from March 1992 to December 2001 for high wind events through Guadalupe Pass. The high wind events are caused by cold air surges into the region. (Graph produced by Ryan Barnes)



**Figure 5.** The graph above shows the medium maximum change in density from ELP to CVS from March 1992 to December 2001 for high wind events through Guadalupe Pass. The high wind events are caused by cold air surges into the region. (Graph produced by Ryan Barnes)

## 6. References

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